https://ntrs.nasa.gov/search.jsp?R=20160014659 2019-08-29T17:08:02+00:00Z

Retrievals of Cloud Droplet Size from the RSP Data: Validation Using in Situ Measurements

Mikhail D. Alexandrov[1,2], Brian Cairns[2], Kenneth Sinclair[1,2], Andrzej P. Wasilewski[3,2], Luke Ziemba[4], Ewan Crosbie[4], John Hair[4], Yongxiang Hu[4], Chris Hostetler[4], Snorre Stamnes[4]

[1]Columbia University, [2]NASA Goddard Institute for Space Studies, [3]Trinnovim LLC, [4]NASA Langley Research Center

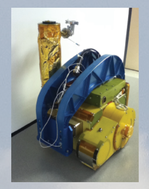
RSP on NAAMES Field Campaign

North Atlantic Aerosols and Marine Ecosystems Study (NAAMES) was based at St. John's airport, Newfoundland, Canada with the latest deployment in May - June 2016. RSP was onboard the NASA C-130 aircraft together with an array of in situ and other remote sensing instrumentation.

Research Scanning Polarimeter

Research Scanning Polarimeter (RSP) is airborne prototype to Aerosol Polarimetry Sensor (APS) built for NASA Glory mission.

RSP



RSP assembly on C-130

Measures total and linearly polarized reflectances in 9 spectral bands (410 - 2250 nm).

Along-track scanner: 152 scene sectors over 121 degrees of scan along track (+/-60° from the normal).

The data from actual RSP scans is aggregated into "virtual" scans, each consisting of all reflectances (at a variety of scattering angles) from a single point at the cloud top.

LARGE's Cloud Droplet Probe

- Forward-scattering optical spectrometer
- Particle diameter (2-50 μm)
- 30 size channels
- Number concentration (0-2000 cm^{-3})
- 20% accuracy
- Liquid water content, Effective diameter
- Typical sample area: 0.24 mm^2
- Air speed range 10-250 m/sec

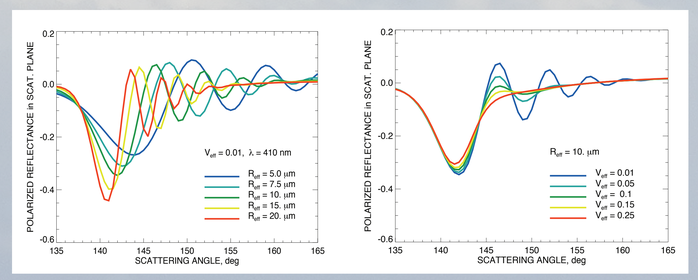
Acknowledgment

NAAMES field experiment and this research is funded by the NASA Earth Venture Suborbital Program.

RSP cloud retrievals are available from http://data.giss.nasa.gov/pub/rsp/

Cloud droplet size retrieval algorithm

We utilize the scattering angle dependences of the polarized reflectances with the focus on the sharply defined rainbow structure within the scattering angle range between 137 and 165 degrees. The shape of the rainbow is determined mainly by single scattering properties of the cloud particles.



Sensitivity of polarized reflectance to the effective radius (left) and variance (right) of cloud droplet size distribution.

Total reflectance: $R(\theta) = \dfrac{\pi\, I(\theta)}{\mu_s\, I_o}$ **Polarized reflectance:** $R_p(\theta) = -\dfrac{\pi\, Q(\theta)}{\mu_s\, I_o}$

I_o- TOA irradiance, μ_s- cosine of SZA, θ - scattering angle

We fit measured polarized reflectance as

$$R_p(\theta) = a\, R_p^{(Mie)}(\theta, r_{eff}, v_{eff}) + b\,\theta + c$$

where $R_p^{(Mie)}$ are computed using Mie theory (single scattering) for a grid of r_{eff} and v_{eff} assuming Gamma size distribution. Parameters *a*, *b*, and *c* account for the effects of multiple scattering.

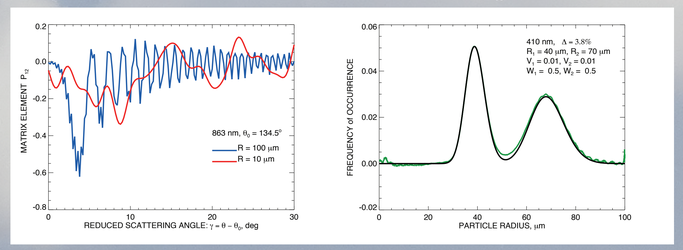
Rainbow Fourier Transform (RFT)

Mie-theory-derived polarized reflectance $F(r, \gamma)$ as a function of reduced scattering angle (in the rainbow angular range) and the (monodisperse) particle radius appears to be a proxy to a kernel of an integral transform (similar to the sine Fourier transform on the positive semi-axis):

$$\hat{n}_a(\gamma) = \int_0^{\infty} n_a(r)\, F(r, \gamma)\, dr; \qquad n'_a(r) = \int_0^{\gamma_{max}} \hat{n}_a(\gamma)\, F(r, \gamma)\, \gamma^2\, d\gamma.$$

This allows to retrieve the shape of the (area) droplet size distribution $n_a(r)$ by the application of the corresponding inverse transform to the observed polarized rainbow.

This non-parametric approach does not require any *a priori* knowledge of the droplet size distribution functional shape, no look-up tables, no fitting, computations are the same as for the forward modeling.



RFT's basis functions $F(r, \gamma)$ (above left) are not exactly orthogonal, so this procedure is complemented by a simple regression technique removing the artifacts. Right pannel shows a model area size distribution (black) and the corresponding RFT retrieval (green).

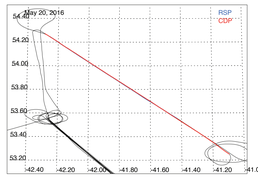
In situ validation during NAAMES field experiment

During NAAMES campaign a number of flight patterns were performed when C-130 flu along the same linear segment at one time at the cloud top making in situ measurements, and at another time above clouds where RSP could operate. We compare in situ droplet size distributions (DSD) retrieved from RSP data with in situ measurements made by the Cloud Droplet Probe (CDP). Distances between RSP and CDP ground tracks were about 200 m.

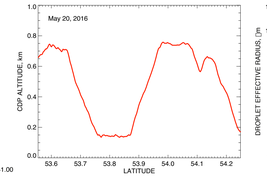
May 20, 2016. RSP: 12:44 – 12:53; CDP: 13:17 – 13:37 UTC

Comparisons for this segment are possible when C-130 is at cloud top. RFT inconclusive due to oscillations.

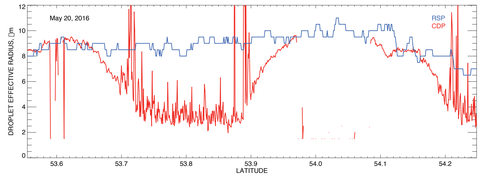
Flight ground track



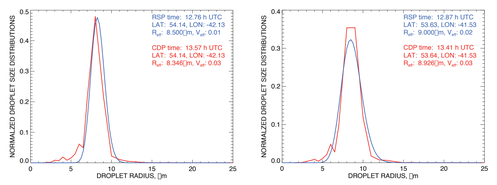
Flight altitude (for CDP)



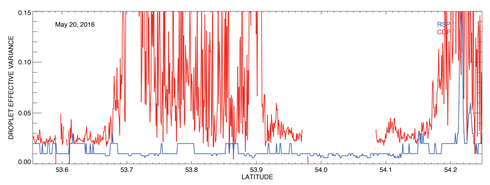
Droplet effective radius (parametric retrievals)



Droplet size distributions (parametric retrievals)



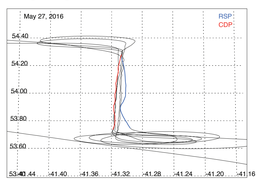
Droplet effective variance (parametric retrievals)



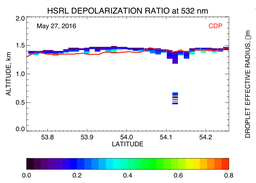
May 27, 2016. RSP: 15:06 – 15:12; CDP: 14:39 – 14:47 UTC

Deviations between RSP and CDP are due to a second DSD mode likely corresponding to another cloud layer.

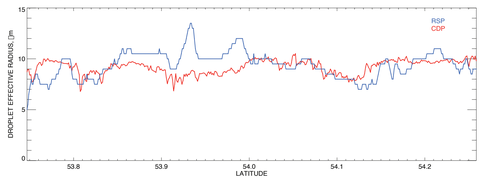
Flight ground track



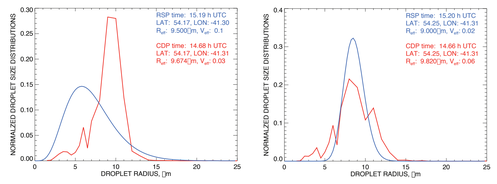
Flight altitude (for CDP)



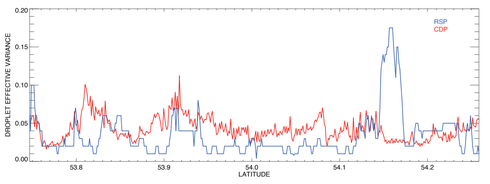
Droplet effective radius (parametric retrievals)



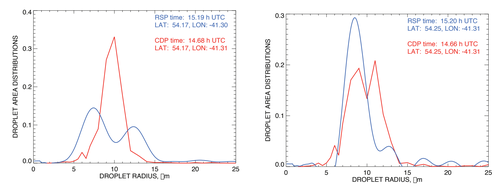
Droplet size distributions (parametric retrievals)



Droplet effective variance (parametric retrievals)



Droplet size distributions (RFT)



Effective radius and fraction of DSD modes (RFT)